Volume 42 APRIL, 1956 Number 4

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

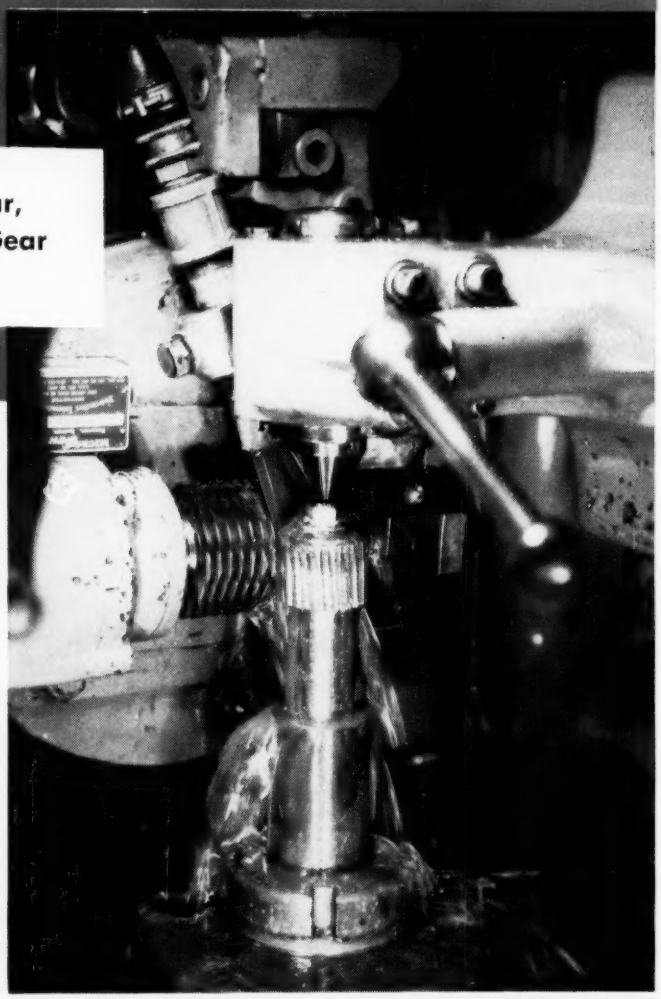
This Issue

CUTTING FLUIDS

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

HOW WE QUADRUPLED TOOL LIFE—and cut tool cost 75%

—as told by George Edgar, Foreman, D. O. James Gear Mfg. Co., Chicago, Ill.



"THE JOB was hobbing a small helical gear," says Mr. Edgar. "With the cutting oil we have been using we averaged about 125 gears between resharpenings after using the full face of the hob.

"A Texaco Lubrication Engineer offered to help us do better. On his recommendation, we changed to *Texaco Transultex Cutting Oil B* and found we could run 500 gears before hobs had to be sharpened. This gave us four times the tool life and cut our tool costs on this job by 75 per cent."

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JOB DATA

Steel *AISI 4140*	No. of teeth *19*
Hardness *Rc 30-35*	Diam. Pitch *12.037*
Diameter *1.75"*	Hob Diam. *3.50*
Face *0.75"*	RPM *110*
Shape *Helical*	Feed *0.070"*
	SFPM *101*

TEXACO

TEXACO CUTTING, GRINDING AND SOLUBLE OILS FOR FASTER MACHINING

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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CUTTING FLUIDS

METAL CUTTING has long been an art, but now through the combined efforts of the physicist, the chemist, the metallurgist, and the engineer, it is currently in the process of being transformed into a science. Great strides have already been made in establishing some of the basic principles and underlying laws that govern the cutting and machining of metals. Although the story of metal cutting is far from being complete and much additional basic work still remains to be done, fundamental information is being accumulated at such rapid rates that it appears the time is not far off when all of the variables that influence the operation will be identified and their inter-relationships established.

One of the major factors contributing to the overall advancement and progress of the metal cutting industry has been the availability of high quality cutting fluids. By the proper use of a suitable fluid, substantial increases in tool life and improvements in surface finish can be realized, both of which are of paramount economical importance to the industry. Most of these cutting fluids are supplied by the petroleum industry, and they represent years of continuous research and development. Current demands on the metal cutting industry are greater than ever before, and the ultimate success in meeting the challenge will be contingent in a large measure upon the petroleum companies furnishing larger quantities of even higher quality cutting fluids.

ROLE OF CUTTING FLUIDS

Anyone concerned with the machining of metals should be well aware of the importance of cutting fluids to the success of most operations. Frequently these fluids are referred to by such terms as "cure-all," the "great-compensator" or the "equalizer." Often they are expected to solve all machining problems. When properly selected, handled and applied, they can be of tremendous benefit. However, they are not miracle fluids and it must be recognized that there are many machining problems that cannot be solved simply by the application of a cutting fluid.

Two fundamental processes take place in all machining operations:

1. Formation of the chip from the metal work piece by the tool.
2. Movement of the chip up the face of the tool.

The total work performed by the cutting tool in removing metal is essentially the sum of the work required to form the chip plus that used in overcoming the friction at the tool face. These two quantities are not mutually independent, and usually any factor which affects one of them will affect the other in the same direction. For example, any steps taken to decrease the friction between the chip and the tool also will decrease the amount of work required to form the chip.

Most of the work performed in a cutting opera-

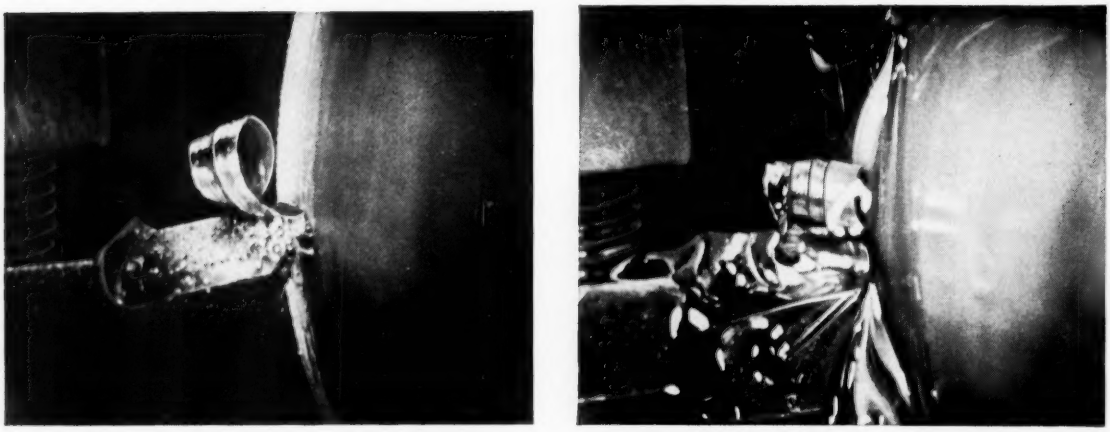


Figure 1 — Close-up comparison of turning operation on 4140 steel dry (left) and with (right) application of a transparent, compounded cutting oil. Notice difference in chip formation.

tion is translated into heat. Heat is produced when the chip is formed from the workpiece and additional heat is developed when the chip moves over the tool face. The extent of both the heat of formation and heat of friction is a function of the operating variables and the nature of the tool and work material. For example, if the metal being machined is brittle, the chip will usually break and crumble, resulting in but little frictional heat. On the other hand, with a long, curled chip, as obtained in the machining of some alloy and mild steels, the pressure with which the chip is forced against the tool face may be extreme, producing high frictional heat. Also the amount of heat formed in machining harder and tougher steels will be greater than that produced in machining brass or low carbon steels.

In any event, heat can be extremely detrimental both to the cutting tool and to the surface of the machined metal. Exact correlations between temperature, tool life and forces in metal cutting are far from being firmly established. However, there does seem to be a direct relationship between the temperature at the chip-tool interface and the life of the tool. As the temperature increases, the ability of the tool to withstand the forces exerted upon it decreases rapidly. It has been demonstrated rather conclusively that a very small change in temperature can have a very large effect on tool life. Consequently, in the interest of long tool life, the temperature at the chip-tool interface should be kept as low as possible. Also it is frequently imperative, particularly in grinding operations, that the workpiece be kept cool to prevent inaccuracies in dimensions and changes in surface hardness. Thus, any practical means of either removing the heat quickly or reducing the total amount of heat formed, or both, is extremely desirable. Cutting fluids can be effective in both respects. Essentially, cutting fluids have two basic functions:

1. As a coolant — cool the tool so as to reduce abrasive wear and loss of hardness, and cool the work to prevent distortion and dimensional inaccuracies.
2. As a lubricant—lubricate the chip-tool interface to reduce frictional heat, tool wear, and power consumption, and improve surface finish; also prevent welding of metal to tool point and subsequent rough surfaces due to "sloughing-off" of the "built-up edge" on the finished face of the work.

In addition to these main functions, there are also numerous secondary but important requirements which cutting fluids must satisfy. For example, they should (1) flush chips away from the work area, (2) protect the finished work surfaces, the tools, and the machines against rust and discolorization, (3) not smoke or fog in use, and (4) have reasonably pleasant odors.

Cutting fluids can be divided conveniently into two broad groups, namely (1) cutting oils and (2) soluble oil emulsions. As might be expected, cutting oils are most effective as lubricants, thus reducing the amount of heat formed. On the other hand, the soluble oil emulsions act primarly as coolants, thereby removing heat that has formed.

Cutting Oils

The lubrication problem created by movement of the chip over the tool face is basically the same as when any surface moves over another at high speeds and under high pressures. The type of lubricant most suited to reduce friction and heat is dictated by the type of metals in contact and the conditions under which one moves over the other. In cutting and grinding operations there are many

possible combinations of tool, workpiece, and operating conditions. These in turn create a wide variety of lubrication requirements ranging from very mild to most severe. Consequently, there must be numerous types of cutting oils available to satisfy the various needs. No one product is entirely suitable to meet all of the existing requirements. In some instances, a straight mineral oil is satisfactory; in others, mildly compounded oils are needed; and for the most severe requirements, very highly compounded products must be used.

The ingredients employed in the compounding of cutting oils include, among others, the following, used either alone or in combinations: fatty oils, sulfur, sulfurized fatty oils, sulfurized additives, chlorinated additives and sulfur-chlorinated additives. The effectiveness of compounded cutting oils is due partly to simple lubrication, but mainly to chemical activity. The surface of the chip in contact with the tool face has just been freshly formed and consequently it is in a highly reactive state. This condition, together with the high temperatures and pressures existent at the point of contact between the chip and the tool, is very favorable for a chemical reaction. The additives in the cutting oil will react with the chip to form metallic compounds. Thus, instead of an actual metal-to-metal contact, the chip and the tool will be separated by a thin layer of a metal compound. If the shear strength of this material is less than that of the metal itself, there will be a reduction in friction with a resultant decrease in the total amount of work and heat. For example, chlorine and sulfur can react to form metal chlorides or sulfides. Fatty oils, on the other hand, can form metallic soaps which reduce friction.

The fatty oils, such as lard oil, by virtue of their polar groups also impart to the cutting fluid the ability to spread and penetrate—a property commonly referred to as "wettability" or "oiliness."

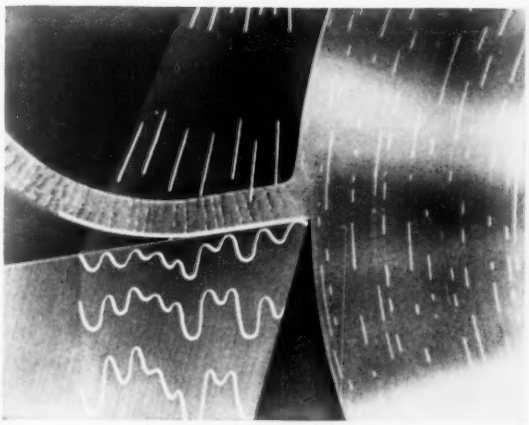


Figure 3 — Diagram illustrating formation of thin film of metal compound between the chip and tool face through application of cutting oil containing extreme pressure type additives.

A cutting oil containing such materials will form a film which will "stay-with" the tool and which will be stronger and less subject to rupture than a film of straight mineral oil. Furthermore these characteristics permit fluids containing fatty oils to penetrate between the tool and the newly generated surface. The tough oil film formed there protects the surface from being marred by bits of abrasive materials which may be present and results in improved surface finishes.

Sulfur in cutting oils is frequently classified as being either "active" or "inactive." In many instances, this results in misunderstandings, since it is usually assumed that sulfur must be classified as "active" in order to be effective in a cutting oil. Actually, the terms "active" and "inactive" as commonly used merely refer to how the sulfur affects a copper strip at a specified temperature. For example, the standard procedure is to contact a copper strip with the oil at 212°F. If the strip is not discolored, or is only slightly tarnished, the sulfur

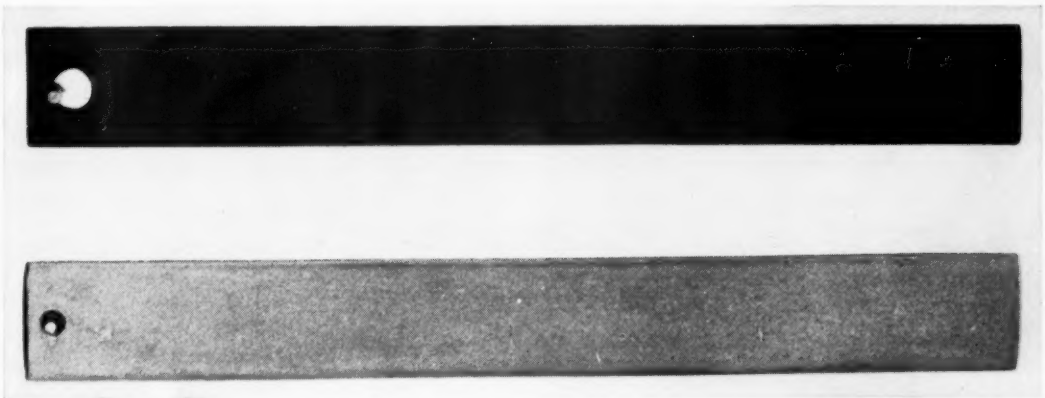


Figure 2 — Copper strips from corrosion test at 212°F. Oil represented by strip on top contains active sulfur. Oil represented by strip on bottom contains no active sulfur.

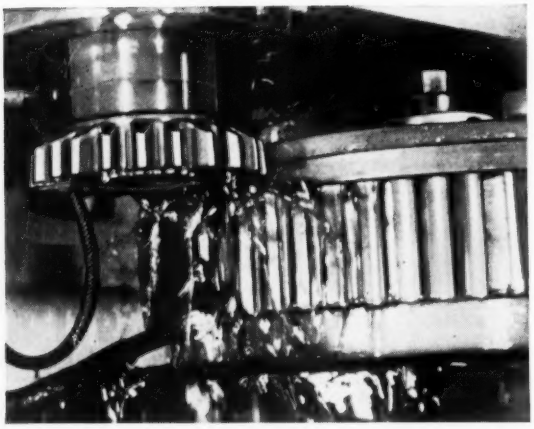


Figure 4 — Example of an application of a transparent, active sulfur type cutting oil.

is termed "inactive." On the other hand, if the strip is badly discolored, the oil is said to contain active sulfur. The temperature at which this determination is made is far below those temperatures normally encountered in machining operations. Simply because sulfur does not discolor a copper strip at 212°F. does not necessarily mean that it will be "inactive" or ineffective at the conditions existent at the tool point. Normally, cutting fluids containing active sulfur should not be employed in the machining of copper alloys or similar materials, since staining might occur. For such applications, products containing inactive sulfur are generally recommended. However, their application is by no means limited to such operations. Cutting oils containing inactive sulfur can be employed satisfactorily on many types of operations.

Although all aspects of cutting oils have been improved throughout the years, the one outstanding trend has been the progress made in the transparent, compounded oils.

Transparency is a property of a cutting oil which not only is highly desirable but also offers numerous advantages in machining operations. With a transparent type product, the operator can observe the cutting tool and workpiece through the film of fluid and determine at a glance if something goes wrong. Inspection of parts is accomplished quickly and easily, with a minimum of delay. This all adds up to increased production and fewer rejected parts. Furthermore, clear oils promote cleaner conditions in the shop or plant, and this has a definite favorable psychological effect on all of the personnel involved.

Until recently it was not possible to incorporate a high degree of compounding in a cutting oil and still retain its transparency. The available additives which had to be employed to impart extreme pressure characteristics would darken the oils and, when used in the quantities required, would turn them black. Consequently, the transparent oils had relatively low extreme pressure properties and their applications were very limited. However, considerable research has been done both on the additives themselves and in the methods used to incorporate them in the oil. The results have been extremely fruitful and now it is possible to prepare transparent oils with sufficient compounding to handle most all of the machining operations satisfactorily. Today, the transparent cutting oils are replacing black oils on many operations where, only a short time ago, the latter were considered indispensable.

The cutting oils currently being used throughout industry can be classified by various means in accordance with their compositions. From a practical standpoint, the oils containing additives will fall into one of three main categories, namely (1) transparent, active sulfur type oils, (2) transparent, non-corrosive type oils or (3) dark, sulfurized oils.

Transparent, Active Sulfur Type Oils

These contain active sulfur, in addition to one or more other materials including fatty oils, sulfurized fatty oils and sulfur and chlorine containing additives. They now may cover a wide range of compounding and extreme pressure characteristics and can be employed satisfactorily on all but the most difficult machining operations. Because of their active sulfur content, these oils may stain copper and copper alloys, and if used to machine these materials, a subsequent cleaning operation usually will be required.

Transparent, Non-Corrosive Type Oils

This class of oils differs from the previous group in that they do not contain the so-called active sulfur. They may contain various combinations of fatty oils, sulfurized fatty oils and sulfur and

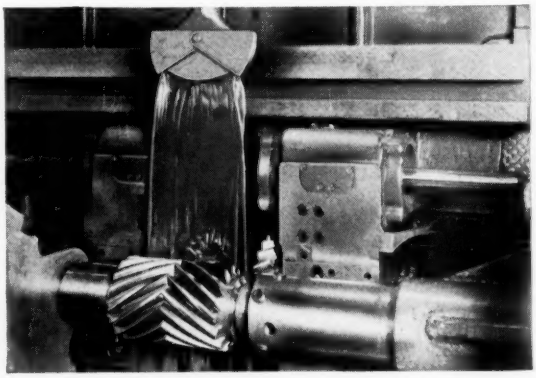


Figure 5 — Cutting a herringbone pinion on a Gear Generator. Note how the work may be observed through the transparent cutting oil.

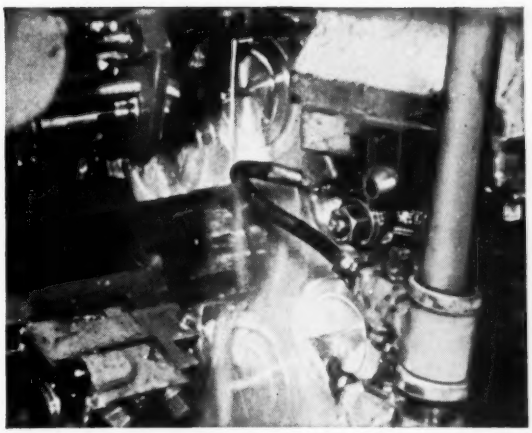


Figure 6 — Application of a transparent, non-corrosive type product as a cutting fluid on an automatic.

chlorine containing additives. Although they are not as highly compounded as the transparent, active sulfur type products and consequently should not be used on some of the tougher operations, they are very satisfactory general purpose oils and will handle many types of machining on both steels and non-ferrous metals. Their non-corrosive feature makes them particularly well suited for use on copper and its alloys, since staining will not occur and cleaning of the machined parts is not required.

Oils in this group may have been designed for applications other than that of a cutting oil. They may be so constituted that they can also be employed as the machine tool lubricant and as the hydraulic oil for those machines which are hydraulically operated. Not all oils in this group are suited for such applications. Those which are, however, combine the characteristics of a good lubricating oil with certain properties required of a cutting oil. They are rightfully termed "Dual" and "Tri-Purpose" oils and should not be regarded as either a cutting oil that may be used as a lubricant or as a lubricant that may be used as a cutting oil. This would infer that the oil was designed for one purpose, but could be substituted for others. Bona fide "Dual" and "Tri-Purpose" products are designed to be both cutting oils and lubricants. The backlog of experience that has been developed over the years has proven their value, particularly in automatic screw machines. In these machines, there often exists a condition wherein, due to leakage, the cutting fluid is mixed with the lubricant and possibly even with the hydraulic fluid. This dilution will reduce the overall compounding of the cutting oil and will soon be reflected in the machining operation. By using the same product for all three applications, there will be no change in compounding on dilution and consistent performance in the machining operation will be achieved.

Even when the nature of the work being processed would require the use of an active type sulfurized cutting oil, a non-corrosive "Dual" or "Tri-Purpose" oil can be advantageously recommended for both the machine lubricant and hydraulic system in machines where leakage is a problem. The reason for this is that dilution of the cutting fluid with the non-corrosive product used as either a lubricant or hydraulic fluid does not have nearly as harmful an effect as that resulting from dilution with a mineral lubricating or hydraulic oil. Therefore, the cutting fluid can be used for a much longer time, efficiency is increased and tool life is extended.

The foregoing use of "Dual" or "Tri-Purpose" oils has been singularly successful in both single and multiple spindle automatic machines. In using such products, however, it can not be stressed too strongly that only new oil should be used in the machine lubricant reservoir and hydraulic system. Reclaimed oil will undoubtedly contain finely divided particles of metal and should not be used for lubrication of any parts of the machine or hydraulic system.

Dark, Active Sulfur Type Oils

Although the transparent type oils are being used more and more extensively, there are still operations where the highly compounded dark or black cutting oils must be used to obtain the desired performance. These may contain the same basic ingredients used in the transparent active sulfur type oils, but since transparency is not a requirement, larger concentrations can be employed to give greater extreme pressure properties.

SOLUBLE OILS

In order for a liquid to be most effective as a

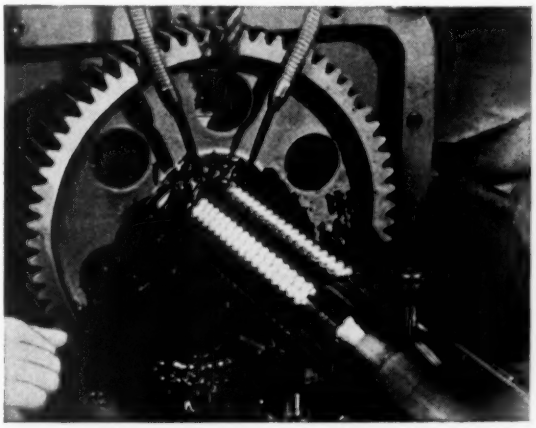


Figure 7 — A dark, sulfurized oil on a heavy broaching operation.

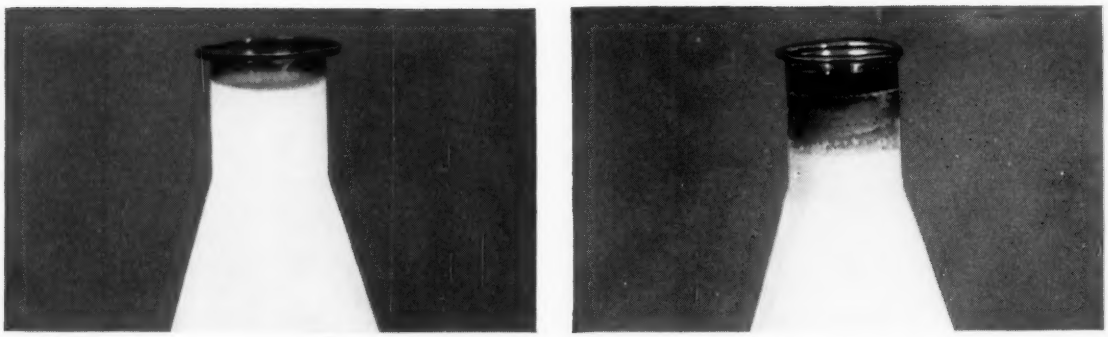


Figure 8 — Stability of soluble oil emulsion is of prime importance. Emulsions of these two different soluble oils were prepared at the same time. After standing a few months, the emulsion on the left is still stable whereas the one on the right has separated.

coolant, it should have a high specific heat, a high thermal conductivity and a high heat of vaporization. Mineral oils are not among the best fluids in these respects and consequently are not particularly effective in removing heat once it is formed. Actually water is about the most efficient cooling medium known. However, there are numerous reasons why straight water cannot be employed as a cutting fluid. Probably the most obvious one, as well as the most important, is its rust promoting characteristics. Also, it has little value as a lubricant. There is a way in which the additional properties desired can be imparted to water. This is through the use of soluble oils. These are oils which have been so compounded that they will form a stable emulsion when mixed with water. Since water is the major component of the emulsions as they are normally used, it still can function efficiently as the coolant. However, the mineral oil and the additives contained therein impart desirable lubricating, anti-friction and anti-corrosion properties to the emulsion. Various combinations of cooling and lubricating properties can be imparted to emulsions by varying the ratio of the soluble oil to water.

Properties of Soluble Oils

Soluble oils are not really "soluble" inasmuch as they do not form a true solution when mixed with water. As mentioned before they form an emulsion and actually should be termed "emulsifiable oils."

An emulsion is a system containing two separate and distinct liquid phases, one of which is dispersed in the other. The liquid which is broken up into globules is known as the dispersed or internal phase. Conversely, the liquid surrounding the globules is called the continuous or external phase. In the soluble oil emulsions used for machining, the oil is the internal phase and the water the external phase.

For two non-soluble liquids to form a homogenous mixture, or an emulsion, a third substance called an emulsifier is necessary. This will be a material containing two types of molecular groups, one of which will orient in the water phase and the other in the oil phase. Consequently, it will be adsorbed at the interface of the two liquids and make the transition between them less abrupt. In a sense, an emulsifier might be regarded as a bridge connecting two dissimilar liquids. By being adsorbed at the interface, the emulsifier serves to decrease the interfacial tension and permits increased sub-division of one of the liquids in the other. In addition, it provides a film surrounding each particle of the dispersed phase and mechanically prevents them from coalescing with each other. Thus, in picturing a soluble oil emulsion, one might visualize a drop of oil enclosed in a film of emulsifier, which in turn is surrounded by water.

The main requirement of a soluble oil is that it emulsify readily with water to form a stable emulsion. This will be a function of the oil, the emulsifiers and the water used to prepare the emulsion. Over and above this requirement, however, most soluble oils contain ingredients to impart certain desirable characteristics or to combat a particular condition that might be encountered in service.

Rust Protection

Next to having good emulsification properties, the rust protection characteristics of the emulsion are probably the most important. Rusting of machined parts is highly undesirable, since its removal is both expensive and time consuming. All soluble oil emulsions will afford some protection against rust formation, if only by virtue of the oil present. Also some of the emulsifiers used are rather good rust inhibitors in themselves. Products offering only borderline protection against rust can be employed in operations where rich emulsions (high ratio of oil to water) can be used, or where the metals being machined are not particularly prone to rust. However, in many cases the rust

protection of these products is quite inadequate. This is particularly true in machining, especially grinding, of cast iron. For operations of this nature, soluble oils are available which contain rust inhibitors to protect against rust, even at very high dilutions.

Detergency

Frequently in grinding operations there is a tendency for the wheels to load rapidly and for the machines to become unusually dirty. This is especially noticeable when using a fine grit wheel to remove a small amount of stock. The emulsion wets the portion of the machine with which it comes in contact and as the water evaporates, an oily film is left behind. This film acts very much like flypaper and holds the fine bits of grinding dirt, along with any dust particles that may be in the atmosphere. The result is a very dirty and unsightly looking machine. Such conditions can be improved by using soluble oils containing increased detergency properties. Most of the emulsifiers commonly used in soluble oils are of the surface active type and have good washing characteristics. Thus in some cases, improved detergency is imparted to the oil by using an additional quantity of the emulsifier. In other instances, another material entirely may be incorporated in the oil by the manufacturer.

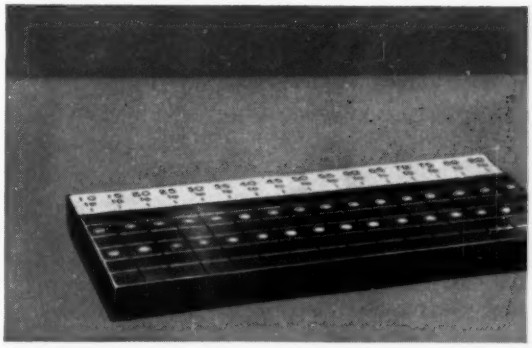
Dirt Settling Characteristics

When emulsions are supplied to individual machines from a central system, it is important that the emulsions returning to the system keep the grinding dirt suspended and prevent it from dropping out in the return lines. Obviously, if this were to occur to any great extent, the lines would soon become plugged and operations would have to be interrupted until they were cleaned. On the other hand, when each machine is supplied from its own reservoir or sump, it is essential that the grinding dirt settle rapidly to the bottom of the sump so that it won't be recirculated to the machining zone where it will interfere with the operation. Thus, depending upon the particular situation involved, the emulsion should either settle dirt quickly or should suspend it. Fortunately, either one of these characteristics can be built into a soluble oil, and it is important that the user select one that will satisfy his own requirements in this regard.

Hard Water

The water used to prepare a soluble oil emulsion will have a pronounced effect on its stability. Actually for best results, distilled water or steam condensate should be employed. Obviously this is far from being practical. In a plant the emulsion must be made with whatever water happens to be available, and it will vary widely in characteristics from place to place. The water may come from a lake or river and be exceptionally soft, or it may be supplied from a deep well and be extremely hard. Hard water is detrimental to the emulsification properties of most soluble oils. The components contributing to the hardness, such as calcium and magnesium, can react with the emulsifier in the oil and form insoluble materials which will separate and form a scum on the surface of the emulsion. That portion of the emulsifier which is so tied up can not perform its intended function, and the resulting emulsion will be deficient in emulsifier. Also the salts in the hard water will tend to be adsorbed in that critical zone at the interface between the oil and the water and cause an increase in the interfacial tension. Thus, in effect, the combination of the depletion of the emulsifier and the adsorption of the salts weakens the bridge holding the oil and water together and makes the emulsion less stable.

Soluble oils are available which have been so compounded as to form stable emulsions with hard water, and they should be used when needed. The



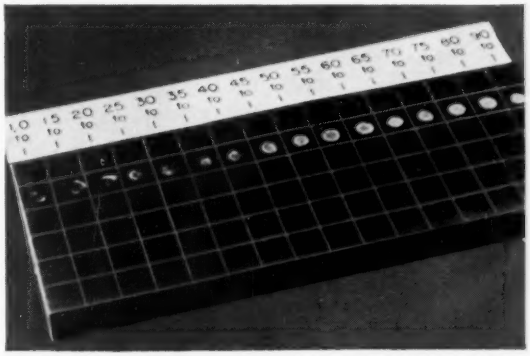


Figure 9 — Rust protection is an essential property of soluble oil emulsions. In the top picture, drops of two different soluble oil emulsions have just been placed on a cast iron plate at dilutions ranging from 10:1 to 90:1.

The bottom picture shows the plate at the end of 24 hours. The rust spots show that one emulsion gave no rust protection even with rich emulsion strengths. The other emulsion gave protection against rust even at high dilutions.

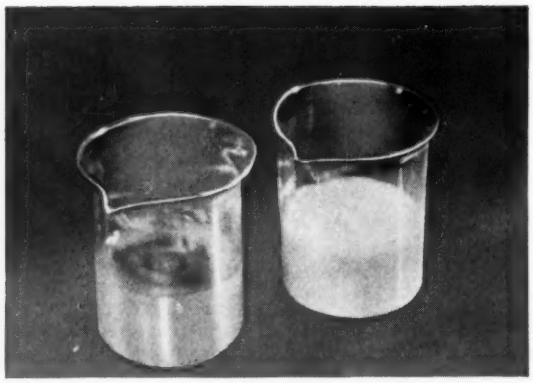


Figure 10 — Where the water is hard, a soluble oil prepared especially for use with such water should be employed. The two emulsions above were prepared from water of 600 ppm hardness.

The soluble oil used to prepare the emulsion on the left is unsuitable for use with hard water as the emulsion is unstable. The soluble oil used for the emulsion on the right, however, is entirely satisfactory.

question is when are they needed? What constitutes hard water? Although there is no hard and fast rule to follow, it is generally accepted that these hard water soluble oils can be used to advantage when the water hardness is over 300 ppm.

Protection Against Bacteria

Soluble oils are sterile as they are prepared. They are also sterile as they are delivered to the customer. However, bacteria can be introduced in an emulsion either through the water used to prepare it or through contamination of the emulsion in service. If permitted to propagate unabated, bacteria can cause some very undesirable results. They are responsible for the unpleasant "Monday morning odor"; they can promote rusting; and they can cause an emulsion to break. Usually a soluble oil will contain a certain amount of bactericide to afford the emulsion some measure of protection against bacterial growth. Obviously soluble oils will vary widely in this regard, depending on the amount and type of bactericide used.

Extreme Pressure Properties

The main difference between the action of soluble oil emulsions and cutting oils in machining operations has already been discussed. It was pointed out that the emulsions are essentially coolants whereas the cutting oils, by virtue of their extreme pressure and wetting properties, act mainly as lubricants to reduce friction. However, there are increasing numbers of soluble oils available today which contain extreme pressure characteristics. They are generally referred to as heavy duty soluble oils and emulsions prepared therefrom combine good cooling capacity with anti-friction properties. In fact, these products can do all but the most difficult jobs which formerly could be handled only by cutting oils.

All in all, soluble oils are among the most complex products that a lubricants manufacturer is called on to prepare. Probably no other petroleum product demands such a delicate balance of ingredients, and the more ingredients present, the more sensitive and delicate is the balance.

The conventional type soluble oils just discussed contain mineral oil as the major constituent and when mixed with water form a milky or opaque emulsion. Products are now available in increasing numbers which form either a translucent emulsion or a transparent solution when mixed with water. The former can be classified as special soluble oils since they do contain various amounts of mineral oils. The translucency of the emulsion is due to a large concentration of the emulsifier base incorporated in the product. The products which form true solutions with water contain no oil and are termed "synthetic" or "chemical" coolants. The products themselves may contain as much as 80% water plus certain chemicals to impart rust protection, detergency and penetration characteristics. The lubricating properties of these coolants generally are quite inferior to those of the conventional emulsions. Also, over a period of time, hard chemical deposits may accumulate on the machine parts. Consequently care should be exercised in using them on machines where the bearings, tool slides and such areas are exposed. Products of both the transparent and translucent type are employed to best advantage in fine-grit, low stock-removal grinding operations.

PRACTICAL CONSIDERATIONS ON THE CARE AND HANDLING OF SOLUBLE OILS

Soluble oils are not prima donna products, but they do require a certain amount of attention in handling and application if top performance is to be expected of them. They are simply sensitive to certain conditions, but if these conditions are understood and properly controlled, soluble oils will be stable and dependable products. Some basic precautions which should be observed in handling soluble oils prior to emulsification are given in Table I.

Frequently, users of large quantities of soluble oils store these products in bulk in underground tanks. It is entirely possible for products stored in this manner to become contaminated with water resulting from either simple condensation or seepage from the outside. Since contamination with water can destroy the balance of the ingredients in the soluble oil and may make the product un-

TABLE NO. I

Precautions in Handling Soluble Oils

1. Avoid Overheating or Excessive Aeration

Overheating or excessive air mixing may upset the water and solvent balance in a formulation resulting in instability. In addition, heating may speed up changes in acidity which could hurt stability.

2. Avoid Contamination

Contamination with water should be avoided. Soluble oils from various suppliers should not be blended or mixed as the mixture may not perform as well as either might do individually. Contamination of Soluble oils with additional mineral oils may also have adverse effects.

3. Protect From Extended Periods of Freezing and Thawing

Soluble oils are not particularly sensitive to low temperature changes and generally may be frozen without serious deterioration. However, continued intermittent freezing and thawing of the products may upset the balance of the components and result in unstable emulsions.

usable, these tanks and the products stored in them should be inspected periodically. Analysis of a sample of oil taken from the bottom of the tank will reveal the presence of extraneous water. Usually the supplier of the soluble oil will be glad to perform this service for the customer.

Preparation of the Emulsion

One of the most important factors influencing the performance and life of an emulsion is the manner in which it is prepared and the nature of the water used. Concerning the mechanics of preparation, there is very definitely a right way and a wrong way. It is just as easy to employ the proper technique, regardless of whether the emulsion is made in a small bucket or in a large central system.

First of all, the equipment used should be clean. This includes not only the vessel in which the emulsion is to be made, but also any containers used to transfer the oil and water. The temperature of the oil at the time of mixing is more important than that of the water. It should be at room temperature. If the temperature is so low that the product is thick and viscous, difficulty may be experienced in emulsification. Oil should be added to the water. *Never add water to the oil.* This is perhaps one of the most common mistakes made in connection with the preparation of soluble oil emulsions. There is always a danger of forming an inverted emulsion, or a water-in-oil type, when the water is added to the oil. This is most undesirable. There should be at least six or seven times as much water in the mixing vessel prior to the addition of the oil as the total amount of oil used. Also for the best emulsification, the oil should be added slowly with agitation. This does not mean that it must be added drop by drop, but neither should it all be poured in at once. It is vitally important that agitation be continued until all of the oil is emulsified.

The ease of emulsification will vary from oil to oil. Some will form an emulsion almost spontaneously, while other will require considerable agitation. The nature of the emulsifiers and the type and number of the additives have a pronounced effect on the ease with which a soluble oil will emulsify. The important point to remember is that an emulsion in which the oil is only partially emulsified will not give optimum performance and usually will cause trouble. Consequently, it is definitely to his own advantage for a user of soluble oils to make sure that the oil is completely emulsified.

Many of the troubles encountered with soluble oil emulsions, can be traced directly to the water used. Consequently, it is likewise to the best interests of the user for him to be thoroughly familiar with the properties of the water which will be employed in the preparation of the emulsion.

As already pointed out, the hardness components of water actually can remove some of the emulsifiers from a soluble oil. If hard water is to be used, there are two courses that can be followed satisfactorily: (1) use a soluble oil that has been prepared

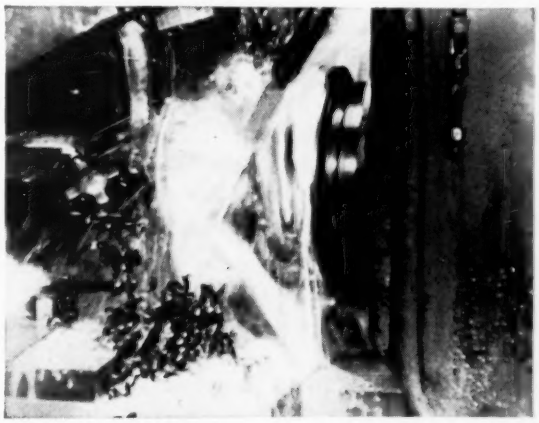


Figure 11 — Application of a general purpose soluble oil emulsion.

TABLE NO. II

Factors in Water Affecting Emulsification

1. Iron, Calcium, and Magnesium Salts
2. Total Solids Content
3. pH (Acidity or Alkalinity)
4. Bacteria or Algae Content

especially for hard water application, or (2) soften the water. If the latter is chosen, advice should be sought from competent personnel as to what to use and how much. Treatment of the water always should be done before the emulsion is prepared and should be carried out in a separate vessel from that used for preparation of the emulsion. This will prevent the scum formed in the softening process from contaminating the emulsion.

Care of Emulsions

Soluble oils are sterile as delivered to the customer. In addition, they generally contain a bactericide or bacteriostatic agent. These kill bacteria or prevent their propagation. However, soluble oil emulsions can support bacterial growth in the water phase and the amount of inhibitor which can be incorporated into the oils cannot protect them completely against all conditions of pollution which may occur in the field. If allowed to develop unchecked, bacteria will destroy essential ingredients through metabolism and, in addition, waste products have a deteriorative effect on the emulsion. In many cases, the odors developed are extremely offensive. There are many ways in which bacterial contamination of emulsions may occur. The microflora may be present in the waters used, particularly in untreated or improperly treated river waters. They may also come from the worker's hands, the metal parts or from refuse cast into the emulsion. Whenever feasible, it is extremely desirable to use waters of zero to low bacteria content for making emulsions. This gives the emulsion a good start toward a long life. The next step in obtaining maximum life and top performance from the emulsion is to be sure that the system into which the emulsion is to be installed is clean and that the equipment and emulsion are maintained as clean as possible during use. A suggested cleaning procedure for preparing bacterially infected soluble oil systems for fresh emulsions is given in Table III.

Even with a properly made, properly cared for soluble oil from which a proper emulsion has been prepared and placed in a properly cleaned machine, it is impossible to predict the service life. This will vary appreciably from plant to plant and from machine to machine depending upon mechanical conditions, as well as on the general cleanliness exercised in the operation. Emulsion life is related directly to the cleanliness and care the emulsion receives during use. The extent to which this should be carried in actual practice will be dependent upon economic factors.

Probably the greatest single factor contributing to soluble oil emulsion deterioration and short emulsion life is bacterial attack. Even if the system has been thoroughly cleaned it is virtually impossible to avoid recontamination, but the bad effects can be minimized. This will depend to some extent upon the personal habits of the operators. The soluble oil systems should not serve as refuse disposals, spittoons or wash basins. These abuses are all too common among machine operators and serve to introduce bacteria into the systems. In addition, the parts being machined may in themselves be a source of contamination and bacteria are present even in the shop air. Cleanliness is a practical means for maintaining a check on this condition. In instances where the emulsion gets out of hand temporarily, the soluble oil supplier will usually make recommendations for remedying the situation. If it involves adding materials such as bactericide to the emulsions, care should be taken as these materials themselves may have extremely adverse effects upon stability and subsequent performance, and furthermore too much germicide may lead to dermatitis.

In addition to bacterial action, there are other factors which will contribute to poor or shorter emulsion life. Frequently the emulsions can be contaminated through the parts being machined for they may bear rustproofing compounds, brazing fluxes, and cutting oils from other operations. Sometimes the contaminant may be just plain dirt or rust. All of these materials may have an adverse effect on the emulsions if concentrations become sufficiently high.

Materials are often added to soluble oil emulsions—sometimes to improve certain properties but

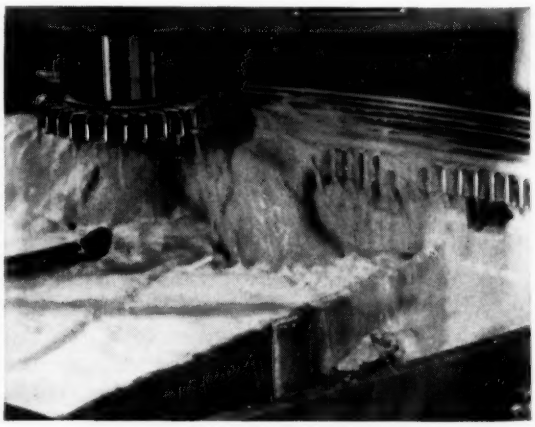


Figure 12 — Application of a heavy duty soluble oil emulsion.

TABLE NO. III

A Procedure for Cleaning Emulsion Systems

1. Drain or pump all of the used emulsion from the system.
2. Disassemble as much of the system as feasible and manually remove chips, sludge or other contaminants from all accessible surfaces.
3. Reassemble equipment and circulate a suitable detergent solution through the system.
4. Drain the detergent solution and circulate an antiseptic or disinfectant solution. Be sure it reaches all surfaces with which the emulsion comes in contact.
5. Drain the disinfectant solution, flush with clean water, and recharge with fresh emulsion.

often for no *good* reason at all! Extraneous materials may be harmless or they may have a pronounced harmful effect depending upon their nature or upon conditions of handling. The effects of these materials should be determined prior to their use, if possible, to keep out of trouble.

It is recognized that contamination of soluble oil emulsions in use will always occur to some extent. The emulsions have to absorb a certain amount of contamination or misuse in service for their use to be practical. However, when difficulties begin to arise in soluble oil systems, a thorough check of the manner in which the emulsions are being handled should be made to determine if they are being abused.

It is a common occurrence for mineral oils from machine leakage to contaminate soluble oil systems. If this becomes excessive, trouble ensues. The oil blankets the emulsion in the sump and by shutting off oxygen or air supply, provides a very productive breeding ground for undesirable bacteria. In addition, when mineral oils are intimately mixed with the emulsion during use, such as on recirculation of the emulsion, these oils may actually extract some of the oil soluble emulsifier and additive components of the soluble oil and take them out of use. This factor may also interfere with proper determinations of emulsion strength by causing the emulsion to appear rich in oil component. Consequently, the concentration of effective soluble oil in the emulsion may fall much lower than desirable. Therefore, it is extremely desirable to provide some means of getting rid of this oil contamination.

On the other hand, water may be lost from the emulsion and this may entail operational difficulties, particularly in grinding applications where chip settling may be adversely affected due to emulsion enrichment. Another factor is that the oily component of the emulsion may be absorbed by the chips formed in the operation, particularly in the grinding of cast iron, so that the emulsions may become too lean for use. All of these various factors have to be watched and a proper check kept on emulsion strength. Experience has shown that three general safeguards, listed in Table IV, are important in obtaining the longest possible service life from an emulsion. These apply not only to single machines but also to large central systems supplying many machines.

There have actually been complaints on dirt settling characteristics of emulsions, where, upon investigation, it was found that the coolant pump suction level was well below the level of the solids settled in the bottom of the machine tool emulsion sump. This caused a high concentration of solids to be recirculated with the emulsion stream. Obviously, such a condition could and should be avoided. In addition it would be extremely desirable in the design of machine tools to incorporate every conceivable feature to aid emulsion preparation, chip removal and general cleanliness. In some shops where volumes are sufficiently large to warrant saving the emulsions, portable filters are used for cleaning emulsion sumps. Actually there are many relatively small devices available for cleaning emulsions, such as paper filters, magnetic filters, and flotation devices. Usually some means can be adapted in a particular shop. In other applications, emulsions are discarded when the quantities of solids limit usefulness or performance, and it is not considered economically feasible to recover the emulsion. There are also a number of large central systems which employ various and complicated means of removing solids, aerating and deoiling the emulsions. These systems when operated properly at a high level of cleanliness will continue to operate for long periods of time without emulsion change, using periodic fresh emulsion addition. On the other hand, when conditions of extreme dirtiness exist, emulsion life even in this type of system is relatively short.

TABLE NO. IV

General Safeguards for Longer Emulsion Life

1. Keep close check on control of emulsion strength. Be sure the oil content represents effective soluble oil and not oil from contamination or so-called "tramp oil."
2. Eliminate as many sources of contamination as possible.
3. Remove chips, grinding dirt, and other contaminants as quickly and as thoroughly as possible.

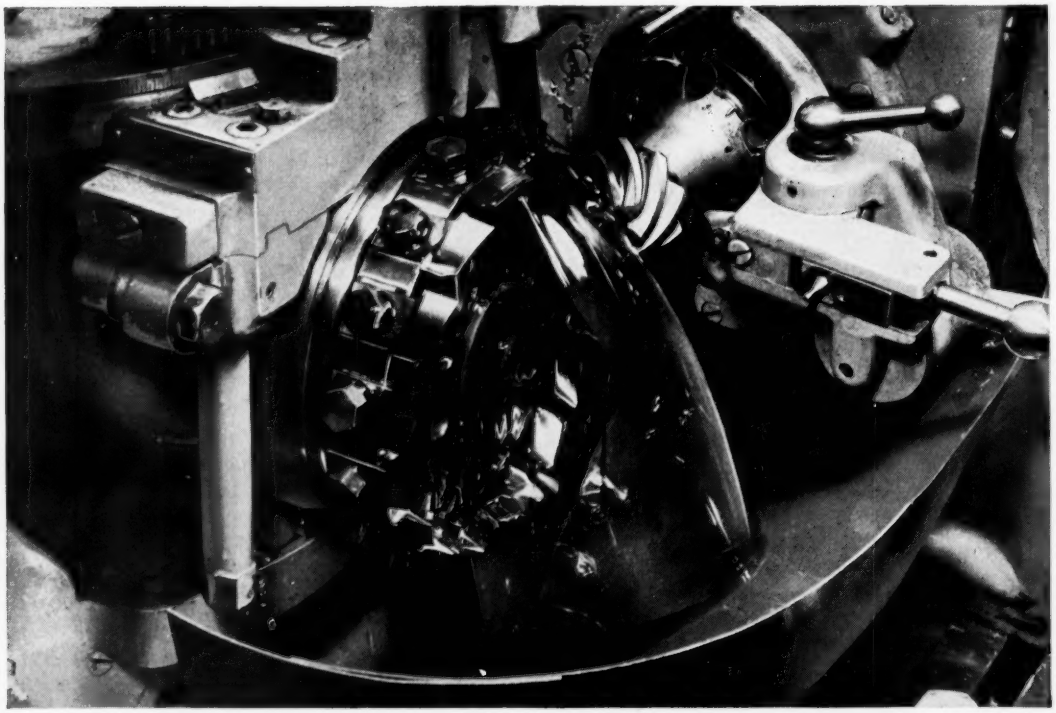


Figure 13 — A view showing the clarity of the film of a transparent type cutting oil as it passes over the tool and work.

Selecting the Proper Fluid

The proper selection of a cutting fluid is a highly complex procedure involving many factors and should be made by competent personnel.

For example, consider the use of soluble oils and surface finish for a moment. In one instance, a soluble oil emulsified with water in a given ratio was being used with entire success until redesign of parts being machined necessitated a better finish. Personnel in charge did not realize that with the specific soluble oil in use a simple change in water to oil ratio would give the desired finish, so they embarked on a time-consuming and expensive testing program of various products. A competent cutting and grinding fluid engineer could have solved their problem with little or no loss in time and production.

In other instances a study of the requirements of a specific application may reveal that by using a different cutting fluid, production may be stepped up, tool life increased enormously, down time reduced, surface finish improved and overall maximum economies realized.

There are several ways of obtaining such economies in any given plant or production shop. First, it is essential that the responsibility for the proper cutting fluids be given to one individual or a group of individuals, depending upon the number of machines involved.

Some plants permit department foremen or even individual machine operators to use proprietary brand name products preferred by them. Unfortunately, this situation leads to unnecessarily high inventories, excellent possibility of misapplications and crowded storage facilities.

Such a situation can be overcome by simple planning and a detailed survey of machine requirements. Surveys can be made by the person or committee placed in charge of cutting fluids selection, or a cutting and grinding fluid engineer from the fluid supplier would be more than glad to make such a survey.

The importance of having responsible parties in charge of the selection of cutting fluids and their application cannot be over-emphasized.

As mentioned before, the proper application of cutting fluids is influenced by many factors, and is so complex that most fluid suppliers have available a corps of cutting and grinding fluid engineers who spend their entire time working with cutting fluids and their application. These persons are highly trained specialists and know how to recommend the most suitable fluid so that unit costs are held at a minimum. Only if a carefully selected product is used and the tool set-up is correct can production be stepped up to maximum output.

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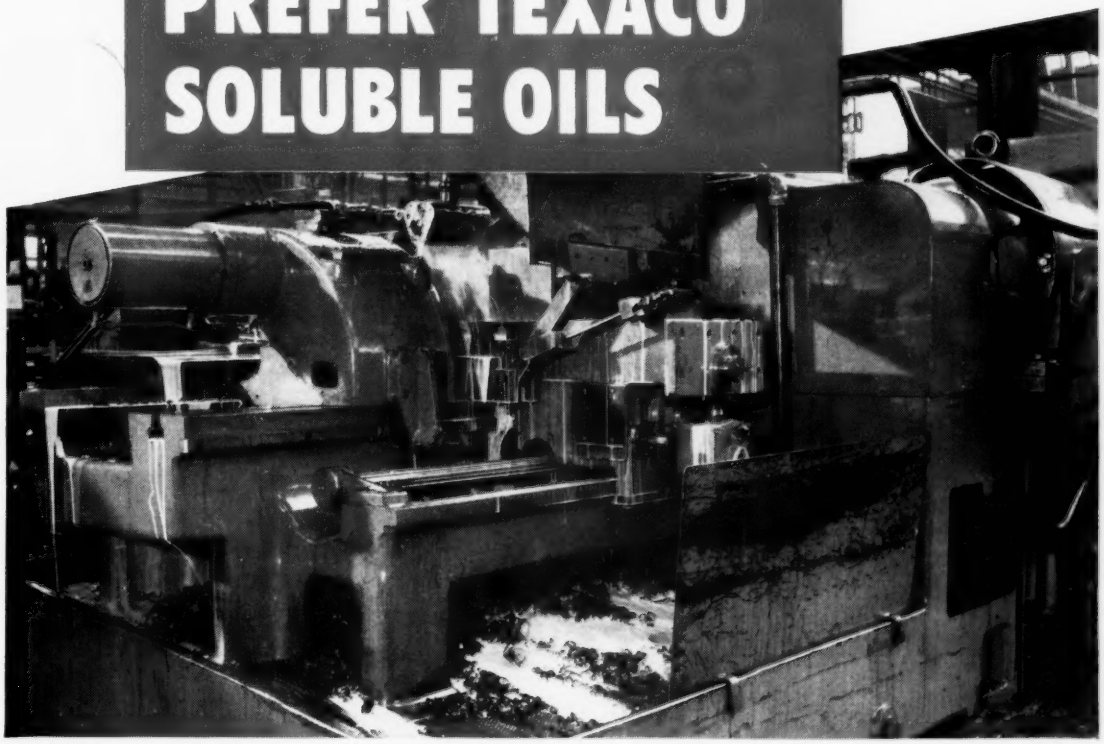

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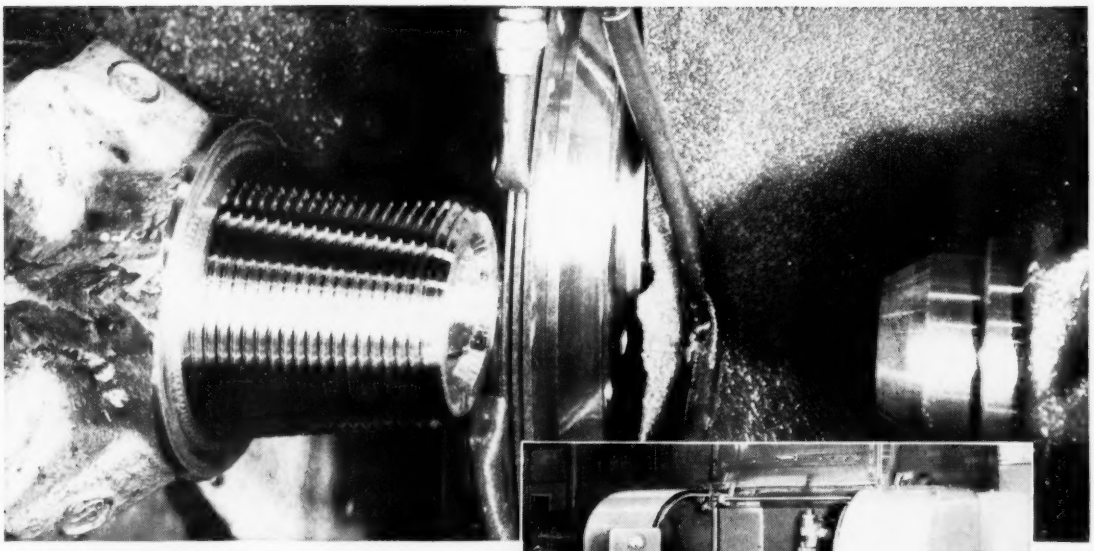

JOB DATA

Machine: Jones & Lamson Thread Grinder
Part: Rock Bit
Thread: 4½ API, 5 threads per inch
Steel: 4620
Wheel: Multi-rib Diamond Dress — **24" dia.** (new)
Speed: 1910 rpm (max.)

Accurate threads . . . fine wheel performance . . . low costs

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